Preprint
UCRL-JC-137788

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This article was submitted to
2000 Fuel Cell Seminar, Portland, OR., October 30-November 2, 2000

U.S. Department of Energy
Lawrence Livermore National Laboratory

August 16, 2000

DISCLAIMER

This work was performed under the auspices of the United States Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

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INTRODUCTION

In 1998, we started the R&D program for the development of high performance planar solid oxide fuel cells (SOFCs) at Lawrence Livermore National Laboratory. The long-term goal of the project is to develop a planar SOFC system running directly on natural gas. The short-term goal is to develop low cost manufacturing techniques and to demonstrate stack power density greater than 1 W/cm2 at 800°C. The high power density will make possible to lower fuel cell operating temperature, thus enabling the use of cheaper materials as well as the direct oxidation of natural gas. This paper summarizes the technical status of the fabrication and electrochemical testings of single cells and stacks.

CELL FABRICATION

Anode-supported cells were used in our investigation because of the potentially high power density. Anode substrates were made from nickel oxide, yttria-stabilized-zirconia (YSZ) and starch as pore former using tape casting. Small samples of 3/4" in diameter were also made using a uniaxial press. Thin film electrolyte was deposited using the Colloidal Spray Deposition (CSD). The CSD technique is a modified version of the conventional colloidal deposition. The technique has been shown to be simple, low cost but extremely powerful. Thin films of thickness ranging from less than 1 micron to several hundreds microns can be easily deposited in a single step using the CSD technique. Due to the simplicity of controlling the pumping solution, multilayer thin film as well as complex film structures with continuously graded composition can also be easily processed using the CSD technique. The process can be adjusted to deposit both dense and porous films, which could be an important simplification in the fuel cell fabrication process. A detailed description of the technique has been described elsewhere (1). Conventional cells had a 10 microns YSZ electrolyte films. Cells with multilayer electrolyte thin films were also prepared for enhanced surface exchange.

Two different electrode materials were used as the cathode. Conventional cells were prepared with the cathode made of a $(La_{0.85}Sr_{0.15})_{0.99}MnO_3$ and YSZ composite. Efforts were made to optimize the electrode microstructure for improved performance. A mixed ionic electronic conductor was used as cathode on the multilayer thin film electrolyte cells. Both electrode materials were deposited using the CSD technique. Figure 1 shows a photograph of an unreduced 2" x 2" sample with conventional cathode.

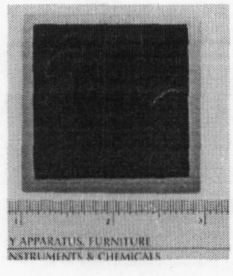

Figure 1: Un-reduced single cell

SINGLE CELL TESTING

Very high power density, up to 2 W/cm2 at 800°C has been reported in the literature for single cells having conventional YSZ electrolyte and Ni/YSZ and LSM/YSZ electrode materials (2,3). However, we have shown recently that certain favorable testing conditions such as the asymmetric electrode configuration (one of the electrode is significantly smaller than the other one) can contribute to an artificial enhancement of the electrochemical performance by as much as 300% or more (4). Therefore only cell testings with symmetric or close to symmetric electrode configurations can be considered as true representative of actual cell performance that can be scalable to stack performance.

Figure 2 shows the performance data for a single cell having conventional electrode materials in (almost) symmetric electrode configurations. The cell was tested in hydrogen/air atmospheres at 800°C. The maximum power density was 1.2 W/cm2. The high power density observed was due to the optimized electrode microstructure.

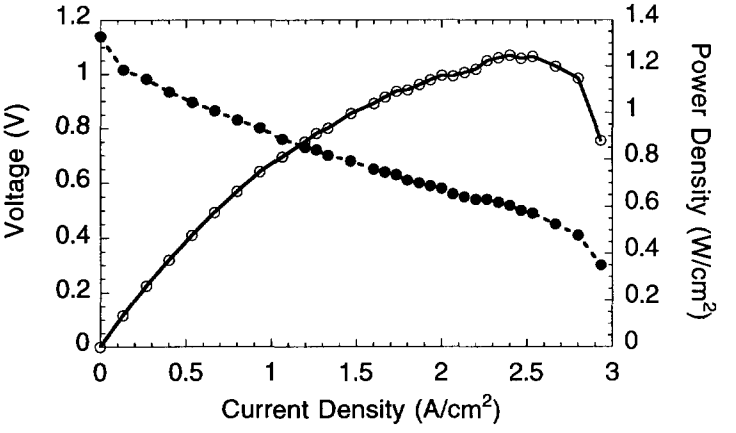

Figure 2: Performance of single cell having conventional electrodes at 800°C.

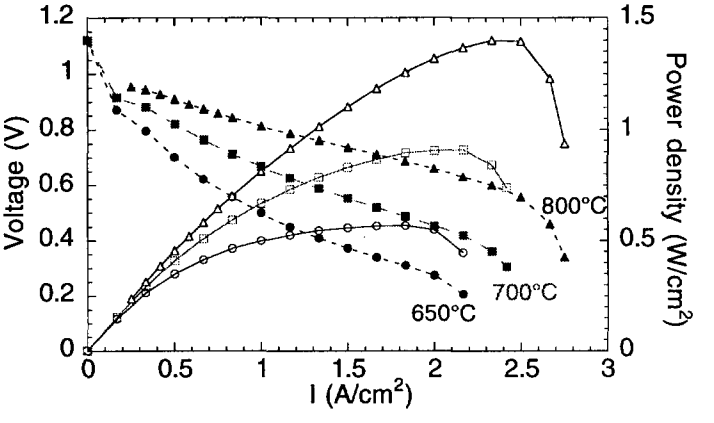

Figure 3: Performance of single cell having multilayer thin film electrolyte and mixed conducting cathode at various temperatures

Figure 3 shows the performance data for a single cell having a multilayer thin film electrolyte and a mixed conductor cathode. The maximum power density was 1.4 W/cm2 and 0.9 W/cm2 at 800 and 700°C respectively. The high power density at temperature below 700°C is promising for intermediate temperature applications as well as for direct operation using natural gas as a fuel.

STACK DEVELOPMENT

A very first fuel cell stack has been assembled using three 2" x 2" cells having conventional electrodes. The conventional cross-flow design was chosen. Plansee Cr5Fe1Y2O3 alloy was used as interconnect material. A photograph of the stack is shown in figure 4. The stack produced a maximum power of 61 W at 800°C in air/hydrogen gases (figure 5). Since each cell had an area of 19 cm2, the maximum power density was 1.05 W/cm2, which is the highest power density reported for a SOFC stack. However, major problems were observed and the stack peak performance decreased rapidly with time. One of the major causes was identified to be the degradation of the interconnect.

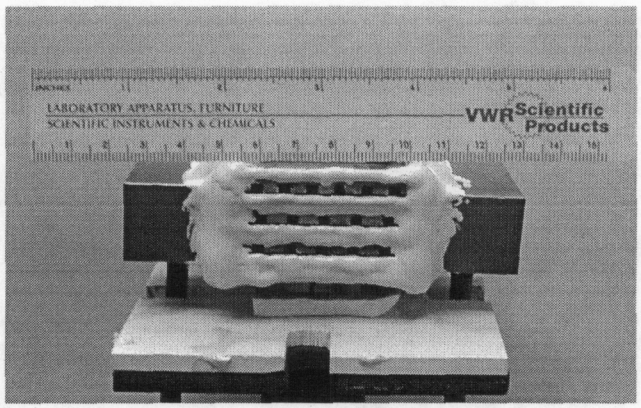

Figure 4: Three-cell stack

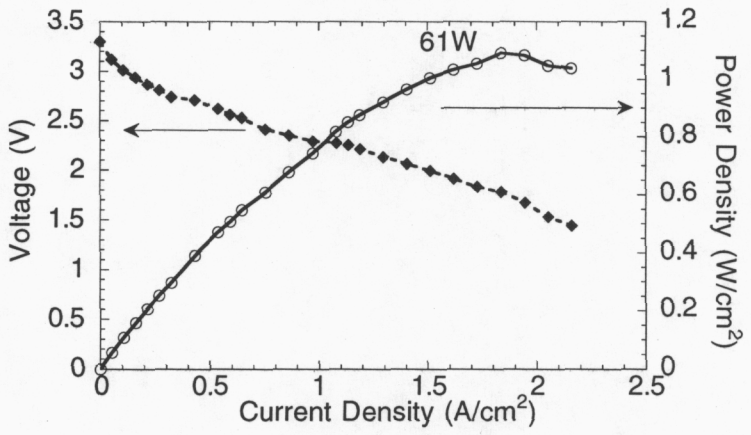

Figure 5: Performance of three-cell stack at 800°C in air/hydrogen gases

CONCLUSION

We have demonstrated single cell performance higher than 1 W/cm2 at 800°C and have been able to scale up that performance to a fuel cell stack. The colloidal spray deposition technique was a key process to fabricate these high performance cells. Using multilayer thin film electrolyte with mixed conducting cathode, higher performance can be achieved. Our effort is now focused on the improvement of the stack long-term performance and to reduce the fuel cell operating temperature.

ACKNOWLEDGEMENTS

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract number W-7405-Eng-48.

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